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Interoperability of EFCI and ERICA ATM switches for ABR services with VS/VD enhancements

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Abstract

To improve network bandwidth utilization, the asynchronous transfer mode (ATM) forum has standardized available bit rate (ABR) service which requires a number of parameters to be negotiated during connection setup. MCR is the minimum cell rate guaranteed by the network and can be used to provide an acceptable quality of service for applications.

In this study, explicit forward congestion indication (EFCI) and explicit rate indication for congestion avoidance (ERICA) switches were adopted in a current transitional ATM network. First, we transfer traffic with ABR service to realize the interoperability of EFCI and ERICA switches. Second, we implemented the virtual source/virtual destination (VS/VD) feature into a homo or heterogeneous EFCI and ERICA switch environment in order to observe the performance. From the simulation results, a smaller queue length was obtained after the VS/VD was introduced into the EFCI and ERICA switches. The high link data transfer utilization with ABR service was also obtained. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Interoperability; Asynchronous transfer mode; Available bit rate; Explicit forward congestion indication; Explicit rate indication for congestion avoidance; Queue length

1. Introduction

The asynchronous transfer mode (ATM) is a cell-switching connection-oriented high-speed technology. It supports applications with distinct quality of service (QoS) requirements, such as

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delay jitter and cell loss and with distinct demands such as bandwidth and throughput. For providing services for a variety of applications, the ATM forum has defined five service categories: constant bit rate (CBR), real-time variable bit rate (rt-VBR), nonreal time variable bit rate (nrt-VBR), available bit rate (ABR), and unspecified bit rate (UBR) [1]. CBR and rt-VBR provide delay and loss guarantees and can be used to transmit delay and loss sensitive multimedia applications. Nrt-VBR provides loss guarantee. ABR and UBR are usually used for transferring data applications. ABR service is suited for a variety of applications since it can economically support data traffic [2]. When the applications run as IP over ATM and transmit data packets in an ATM network, they must divide the packets into cells. The cell loss could cause the retransmission of an entire packet. Hence, it is necessary to apply some congestion control methods to reduce cell loss and increase the throughput.

The ABR service provides minimum cell rate (MCR) guarantees which can be used to transfer general applications to achieve a minimum QoS. It is designed to provide low cell loss and uses close-loop feedback control to indicate network congestion information to the source. The source adjusts their ABR based on the network feedback. Feedback is indicated in resource management (RM) cells, which are periodically sent by the source and returned by the destination. Multimedia applications are the key applications which use the large bandwidth provided by high-speed networks [3]. If the available bandwidth is reduced by congestion, the network will simply disconnect the CBR/VBR connections, because it is currently not possible to renegotiate the contract.

ABR service provides an MCR guarantee, which can be used to provide an acceptable QoS for video applications. Due to the close-loop feedback control, the network switch queue is usually small and the cell loss is low. Multimedia applications can then use the feedback information received by the source to adjust their rates to efficiently use the available bandwidth.

The ATM forum traffic management specifications version 4.0 addresses ABR traffic management issues related to ATM end systems. ABR switch algorithms use either binary or explicit rate feedback to provide congestion information to the end systems. The switch monitors the load on the network and divides the available bandwidth fairly among the competing sources. It is assumed that the sources are adaptive and can change their rates according to the feedback. Here, we only focus on the traffic management issues for supporting delay-sensitive, loss-sensitive, unicast and multimedia applications. In general, some of the ABR switch schemes assume the MCR to be zero. But we can modify it to support nonzero MCRs. For a nonzero MCR, several criteria can be used as defined in the ATM traffic management specifications. Switch algorithms can also be modified to support nonzero MCR.

The advantages of an ATM network, such as high trunk speed, low bit error rate, flexible service type (bandwidth on demand), and high multiplexing capacity make it very much suitable for transmitting multimedia with QoS guarantees. Furthermore, multimedia stream multiplexing reduces the burstiness and bandwidth requirement of the aggregate traffic. The coincidence of many video-stream peaks may result in congestion in the network and degrade the quality of the video. Congestion control is important to guarantee the quality of the multimedia. However, in multiplexed transmissions, efficient bandwidth allocation among the multiple multimedia streams will improve network resource utilization.

Flow control is used to regulate the traffic rate between the sender and the receiver so that a fast/slow transmitter will not result in overflow/underflow at the receiver. When multimedia is transmitted over a dynamically variable bandwidth channel, such as the ABR service of ATM networks, in cases of congestion, the bit rate of the source can be scaled down to help the network recover from congestion [4]. The task of managing multimedia traffic over ATM networks is to regulate the traffic to obtain high network utilization, avoid network congestion and provide an acceptable QoS to the user at low cost.

To improve network bandwidth utilization, the ATM forum has standardized ABR service, which requires a number of negotiated parameters during connection setup [5,6]. In the ABR service, the source adapts its rate to change network conditions [2]. Information about the state of the network, such as bandwidth availability, state of congestion, and impending congestion, is conveyed to the source through special control cells called RM cells. We introduce the basic operation of the closed loop rate based flow control mechanism. When a VC is established, the source end system (SES) sends the cell at the allowed cell rate (ACR), which is set as the initial cell rate (ICR). In order to probe the congestion status of the network, the source sends a forward RM cell every Nrm-1 data cells. Each switch may set a certain field of the RM cell to indicate its own congestion status or the bandwidth, the VC source should use. The destination end system (DES) returns the forward RM cell backward to the SES. According to the received backward RM cell, the SES changes its ACR, which is bound between the peak cell rate (PCR) and MCR. The RM cell contains a 1-bit congestion indication (CI) set to zero and the SES sets an explicit rate (ER) field initial to PCR. When the SES receives a backward RM cell, it modifies its ACR.

$$\mathrm{ACR} = \max(\min(\mathrm{ACR} + \mathrm{RIF} \times \mathrm{PCR}, \mathrm{ER}), \mathrm{MCR}) \text{ when } \mathrm{CI} = 0,$$
$$\mathrm{ACR} = \max(\min(\mathrm{ACR} \times (1 - \mathrm{RDF}), \mathrm{ER}), \mathrm{MCR}) \text{ when } \mathrm{CI} = 1,$$

RIF is the rate increase factor,
RDF is the rate decrease factor.

ABR flow control occurs between a sending end-system (source) and a receiving end system (destination). The source and destination are connected via bidirectional connections. For a bidirectional ABR connection, each connection termination point is both a source and a destination. For the sake of simplicity, only the information flow from the source to the destination with its associated RM cell flows is considered. The forward direction is the direction from the source to the destination and the backward direction is the direction from the destination to the source. As shown in Fig. 1, for the forward information flow from the source to the destination, there is a control loop consisting of two RM-cell flows, one in the forward direction and one in the backward.

A source generates forward RM cells that are turned around by the destination and sent back to the source as backward RM cells. These backward RM cells carry feedback information provided by the network elements and/or the destination back to the source. According to the congestion status and feedback mechanism, there are two kinds of switches: one is the EFCI switch and the other is ER switch [7–9].

2. Explicit forward congestion indication scheme

When congestion occurs, the switch sets the EFCI bit to one (EFCI = 1) in the header of each passing data cell. If a cell with EFCI = 1 has been received by the DES, the DES sets the CI bit to